Lake Monitoring Protocols

Northeast Temperate Network (NETN)

Great Lakes Network (GLKN)

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GLKN Water Quality Monitoring – Inland Lakes Sampling Design

- Monitored annually, 3x/yr
- Index Lakes (N=33)
- Open water season, pref. when stratified

NETN Water Quality Monitoring – Lake and Pond Sampling Design

- Based on Acadia NP program
- Monitored monthly, May- October
- Annual & alternating monitoring at ACAD
- Annual monitoring at other NETN parks
- All accessible lakes > 1 acre (total of 23 in NETN) will be monitored (census)

9 Parks in GLKN
6 with Inland Lakes

- Apostle Islands NL
- Indiana Dunes NL
- Isle Royale NP
- Pictured Rocks NL
- Sleeping Bear Dunes
- Voyageurs NP

Waterbodies in GLKN Parks

Surface Area

	<1 ha	1-10 ha	10-100 ha	100-1000 ha	>1000 ha
APIS	66	9	1		
INDU	49	9			
ISRO	189	60	22	4	1
PIRO	98	17	5	2	
SLBE	9	7	12	3	1
VOYA	237	268	27	4	4

Source - National Hydrography Database; Including beaver ponds, wetlands with open water

Selecting Index Lakes

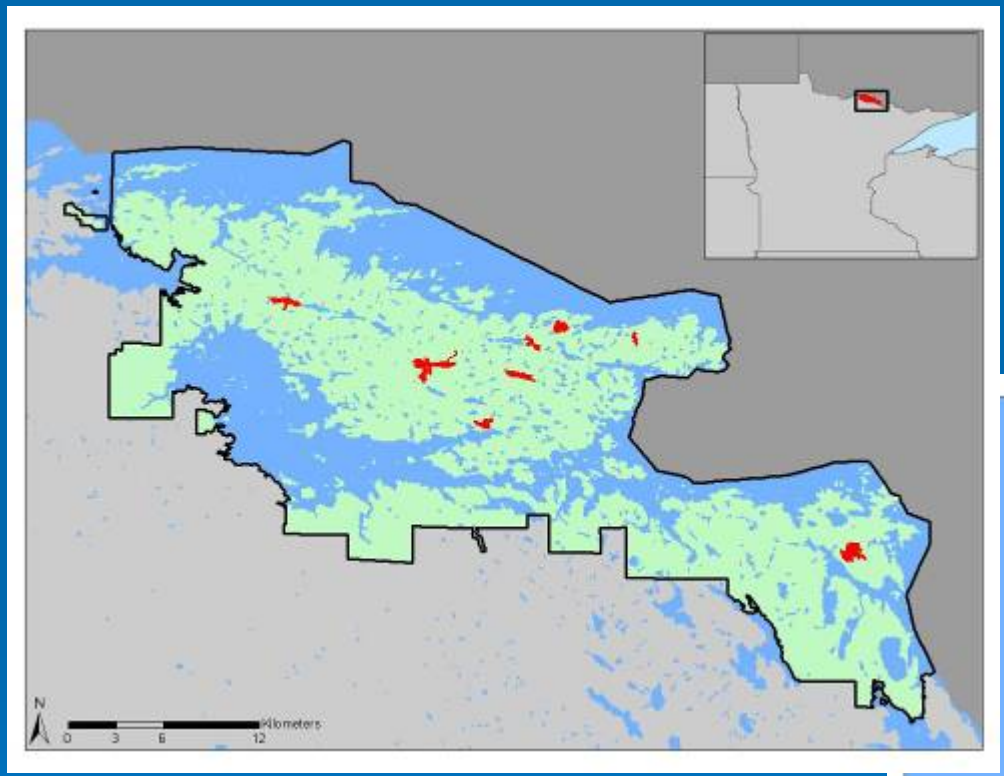
Span gradients of:

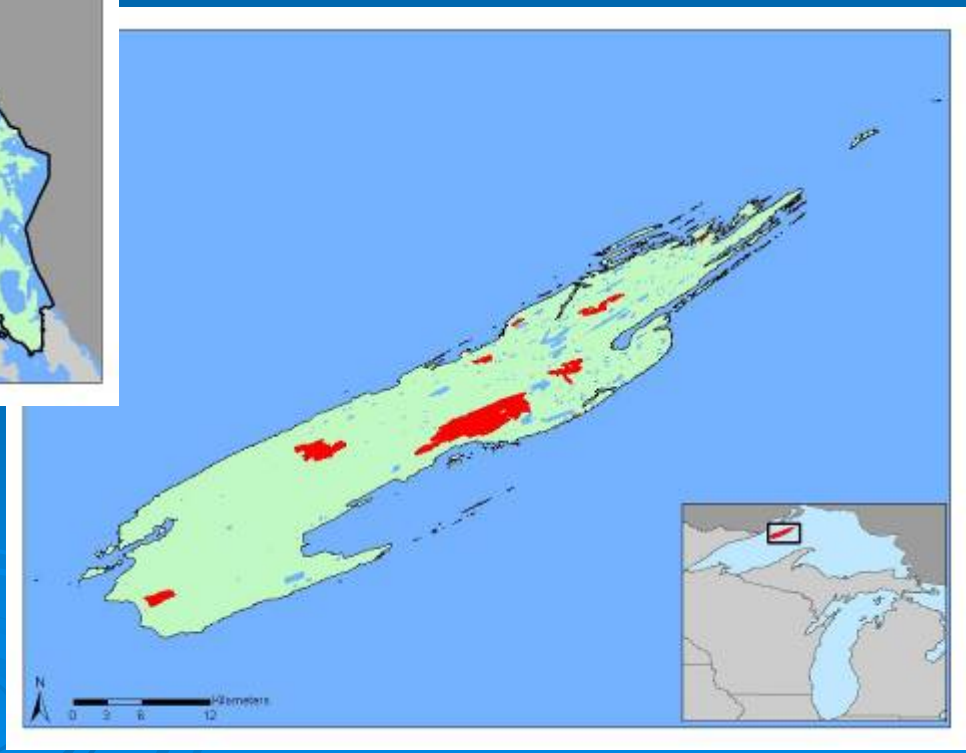
- Lake type (ordination of past WQ data)
- Basin morphometry
- Geographical distribution w/in park
- Visitor use
- Watershed size

Index Lakes Selected

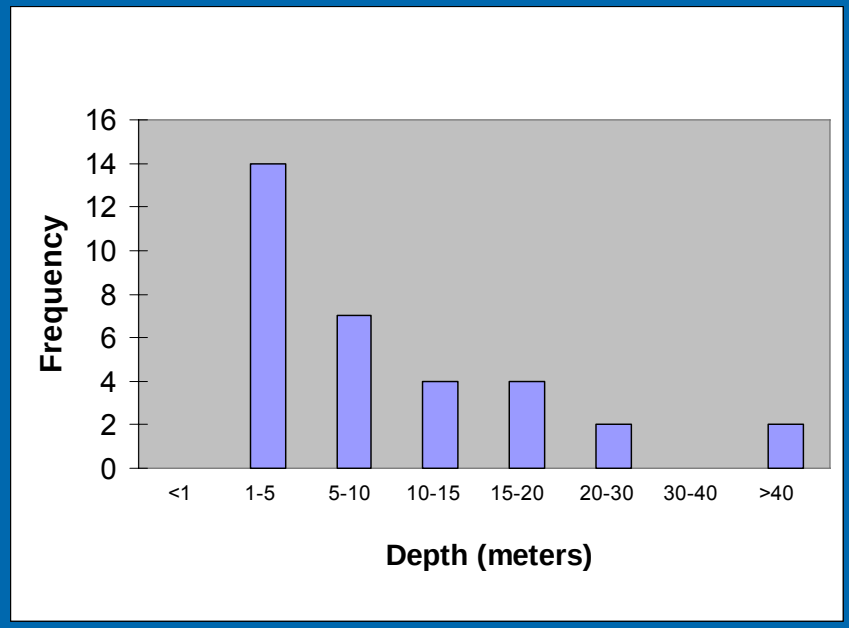
- APIS – 4 lagoons (3 island, 1 mainland)
- INDU – 1
- ISRO – 9 (main island)
- PIRO – 5
- SLBE – 6 (1 island, 5 mainland)
- VOYA - 8

Index Lakes Selected for Voyageurs and Isle Royale National Parks, Showing Spatial Distribution

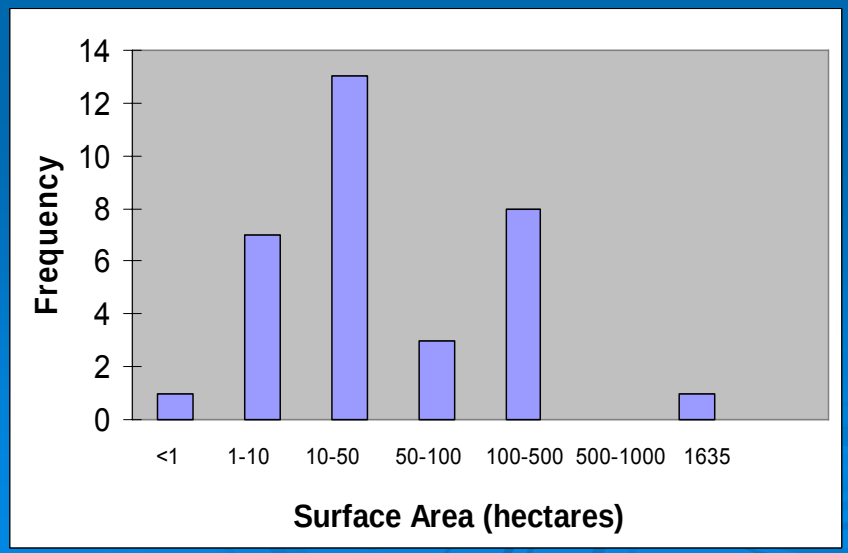




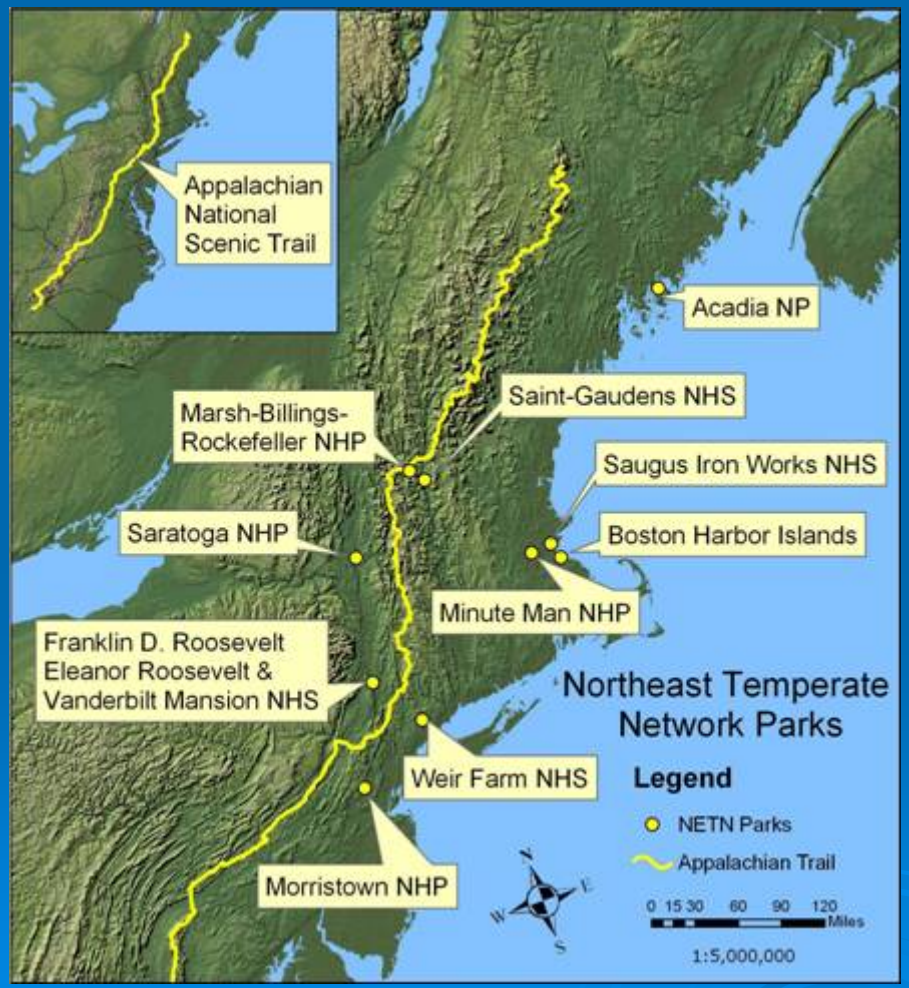
Index Lakes – Frequency Distribution of Zmax



Most index lakes less than 50 ha; one large lake (ISRO)

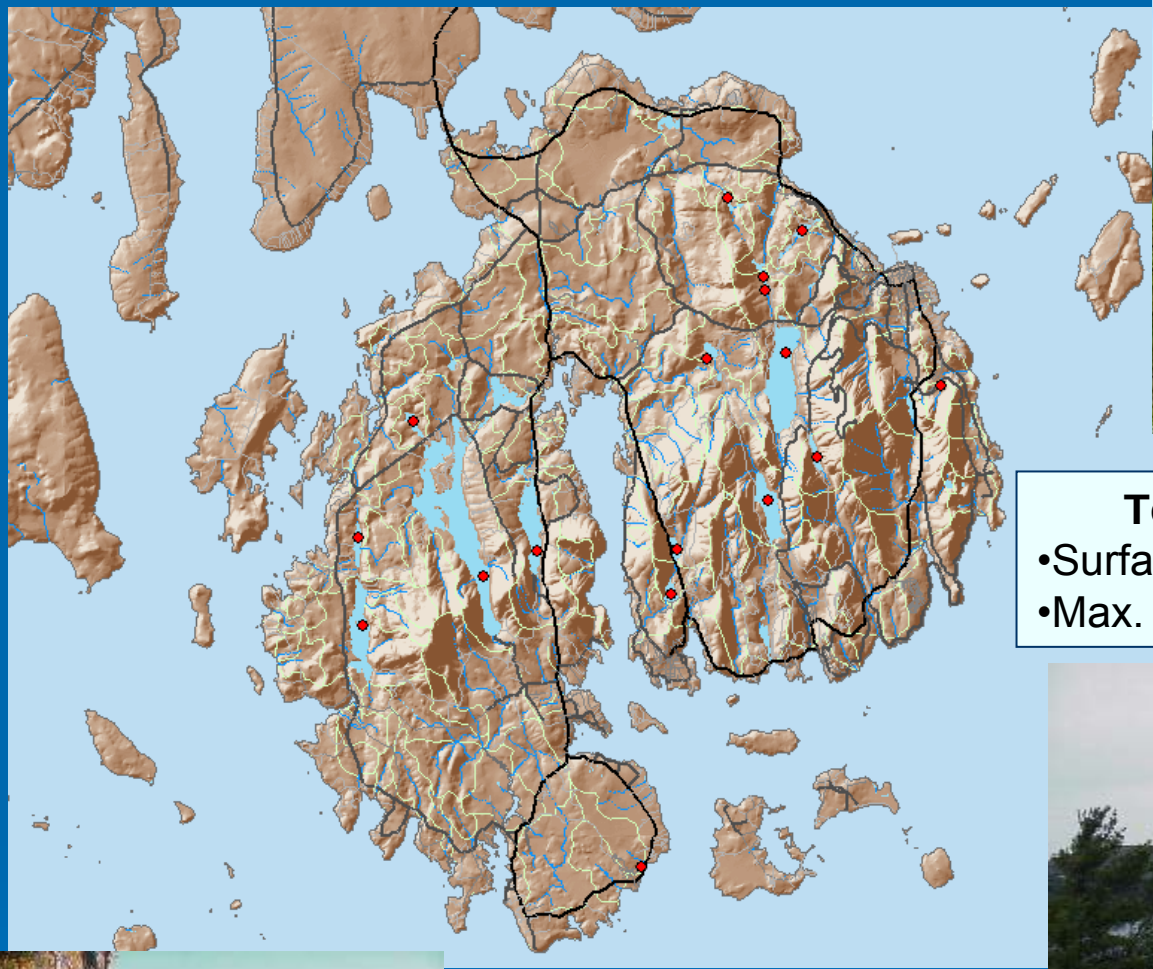


10 Parks in NETN
7 with Lakes or Ponds



Monitoring Sites:

- ACAD: 13 lakes (>15 acres), 7 ponds (≥1- 15 acres)
- MABI: 1 pond
- WEFA: 1 pond
- SAGA: 1 pond



Total of 20 lakes and ponds

- Surface area range: 4.6 to 937 acres
- Max. depth range 0.3 to 51 meters

Acadia National Park Lakes

(all on Mount Desert Island)

Parameters Measured

GLKN

- Core suite
  - Temp, DO, pH, EC25,
  - Clarity,
  - Water level
- Advanced suite
  - Cl, SO_4, Ca, K, Mg, Na, SiO_2
  - Alkalinity
  - DOC, TP, chl-a
  - TN, NO_2+NO_3-N, NH_4-N,

NETN

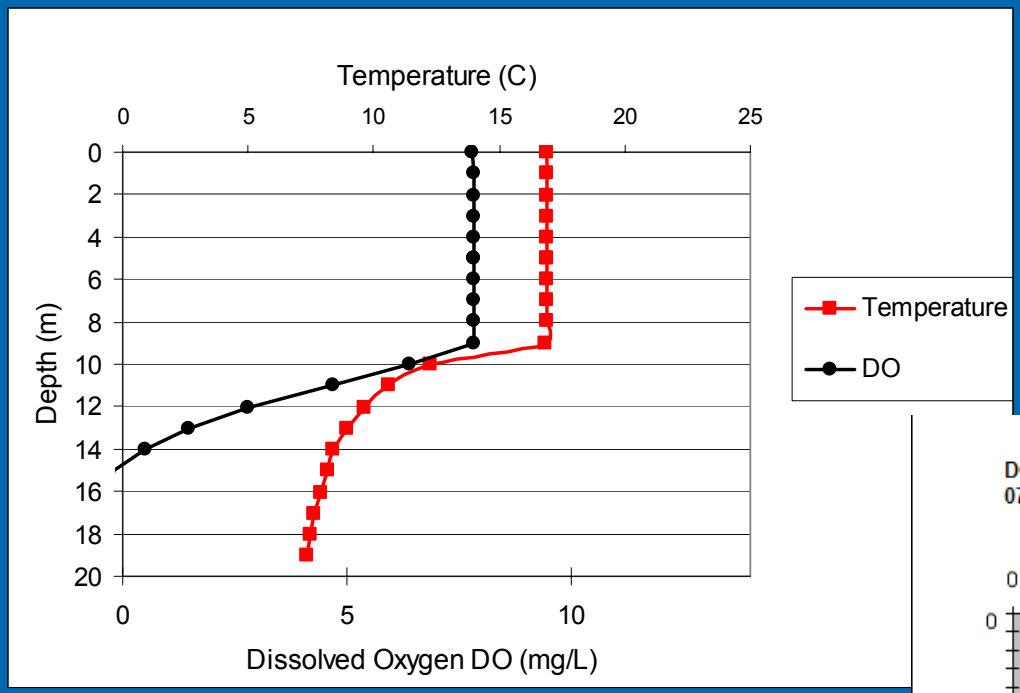
- Core suite
  - Temp, DO, pH, spCond
  - Secchi transparency (or Licor)
  - Water level
- Advanced suite
  - ANC, Apparent color
  - TP, TP_{diss}, PO_4 chl-a
  - TN, TN_{diss}, NO_2+NO_3-N, NO_2-N, NH_3-N,
- Spring/Fall Acidification
  - pH, eqpH, spCond, ANC, DOC, True color, Al, Ca, K, Mg, Na, NH_4, Cl, NO_3, SO_4, TN.

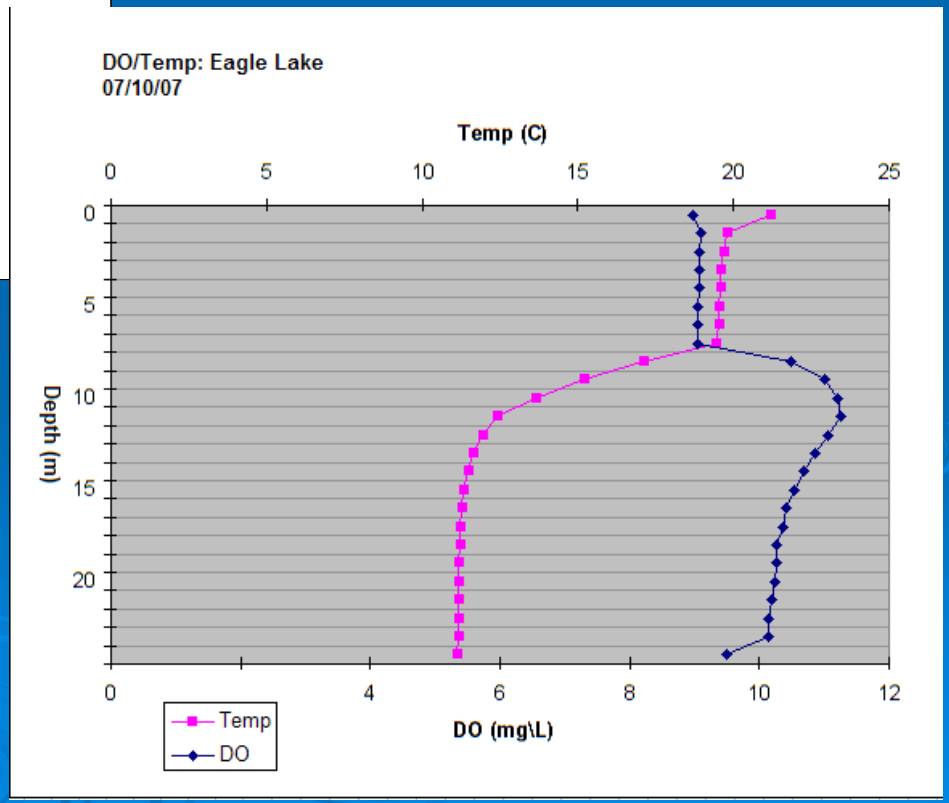
Core Suite Profiles

GLKN

NETN

Typical Late-Season Profile

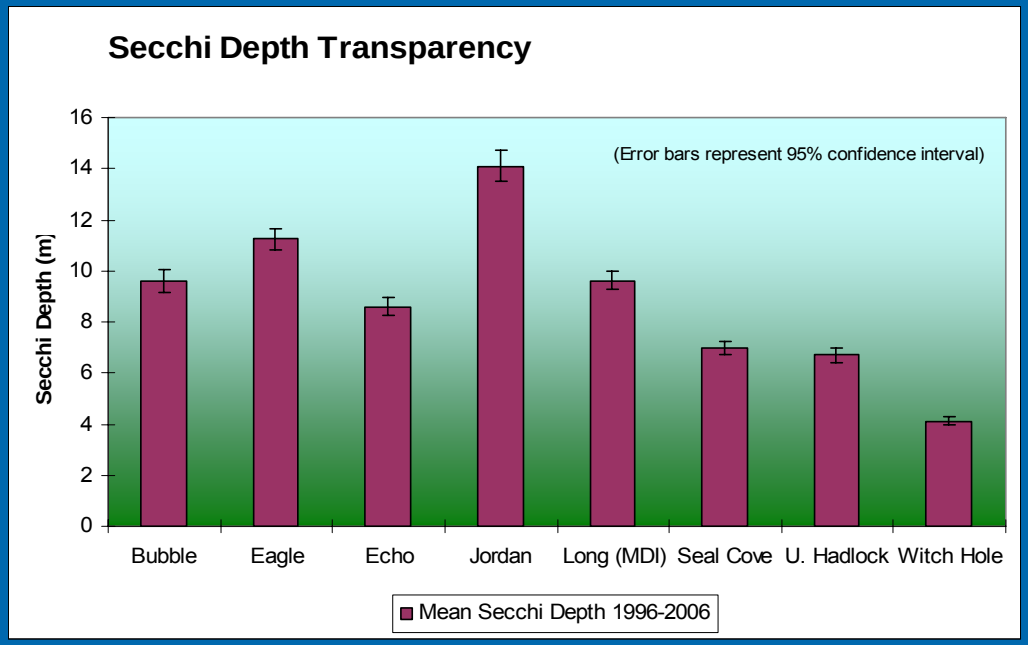


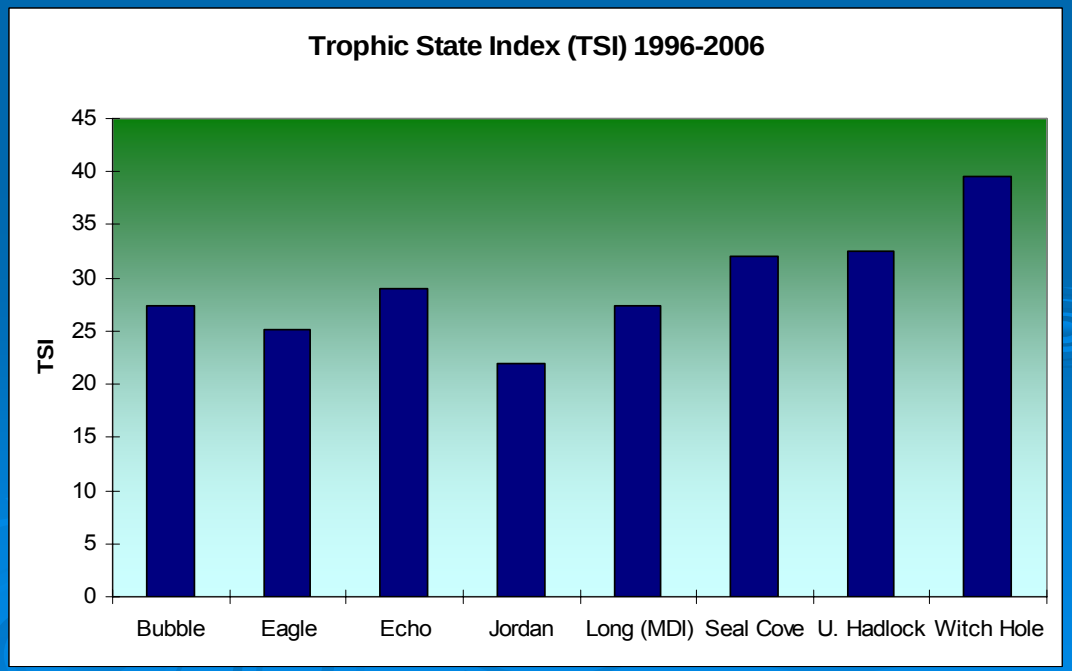


GLKN – Range of Seasonal Means Across Parks

	Max	Min
Secchi (m)	7.8 ISRO	1.4 ISRO
Conductivity (µS/cm)	320 SLBE	7 PIRO
pH (SU)	8.72 ISRO	5.35 PIRO

NETN – Secchi Transparency at ACAD





GLKN: 0-2 m integrated sample

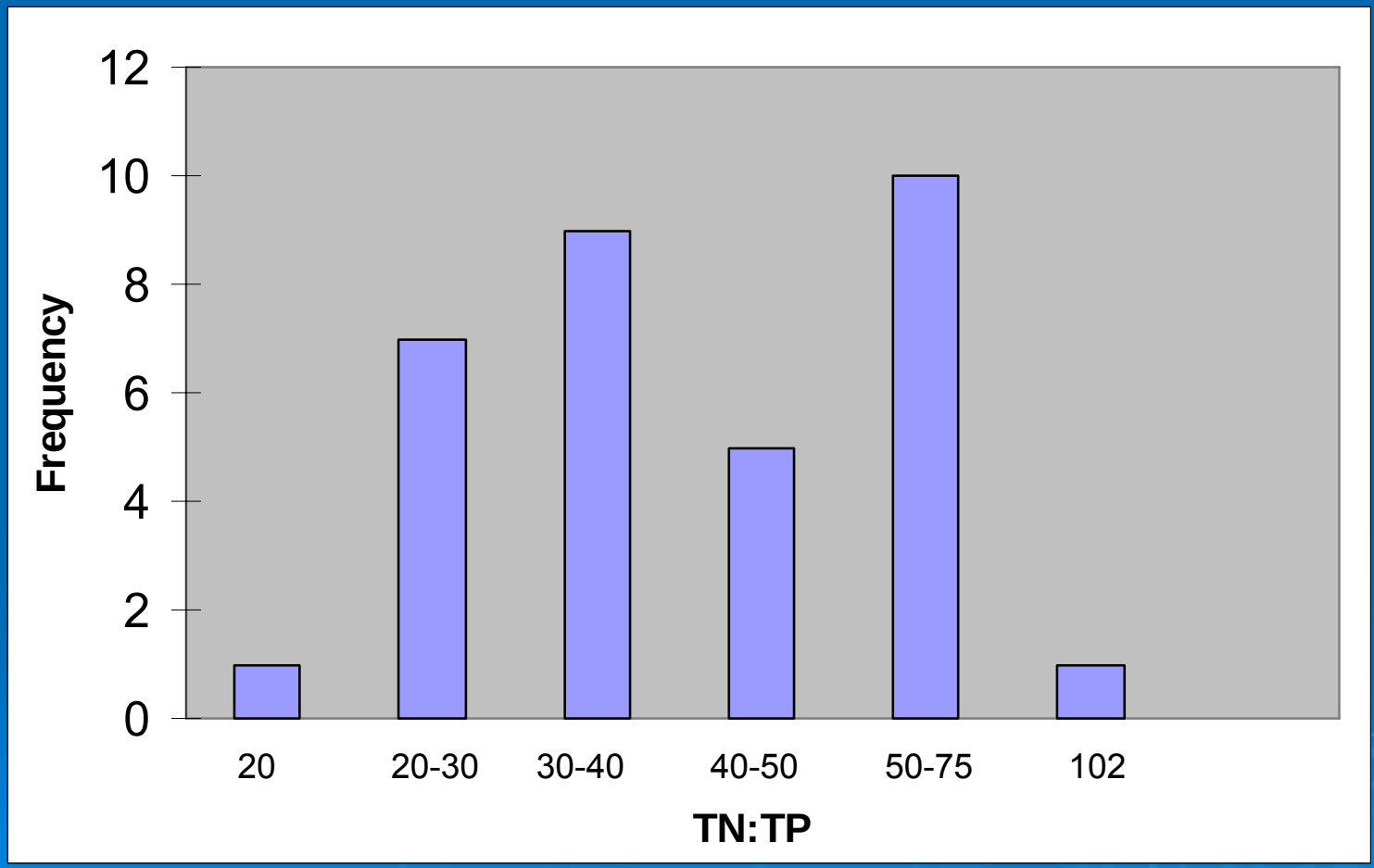
NETN: 0-10 m integrated sample

GLKN – Range of Seasonal Means Across Parks

	Max	Min
Alkalinity (mg/L)	157 PIRO	≤ 4 PIRO, APIS, VOYA
Total P (ppb)	34 ISRO	4 VOYA
Total N (ppb)	818 SLBE	210 VOYA

GLKN 2007 TN:TP Results

all lakes P-limited

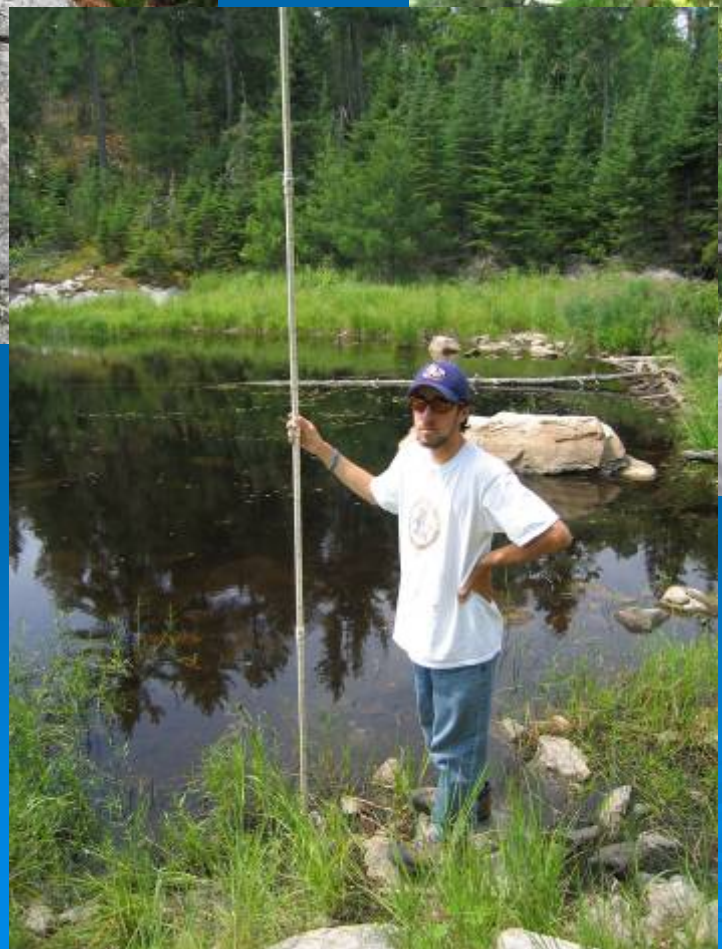


GLKN Range of Travel Time
from park hdqtrs

- ~20 min (one way)
  - SLBE – Tucker Lake
    - 15 min drive to lake
    - 5 min paddle to site
- ~4 hr (one way)
  - ISRO – Desor Lake
    - 1.5 hr boat Lake Superior
    - 30 min paddle to shore
    - 1.5 hr portage to L. Desor
    - 30 min paddle to site

Back-country Sampling

GLKN: Measuring Water Level



Measuring Water Level

- Install reference markers
  - Drill into bedrock
  - Pound rod 1.5m into sand
  - Nail in tree as back-up 1st year

- Using hand level and stadia rod
  measure water level relative to marker

Example Water Level Notes

Agnes Lake Reference Marker
UTM: 15T 5368392N 513742E

6-10-06
water level = - 1.20m

Reference marker on NW side of lake, NE of campsite - straight line distance 34.5 m from fire ring. Below large rock wall ~1.5 m away from water's edge beneath 10"dbh jack pine. Hike along shoreline to large jack pine. Reference marker is 400° from fire ring.

Pictures from campsite toward marker and marker toward campsite.

8-2-06
water level = - 1.305 m

NETN: Measuring Water Level

Oops!

Sonde QA/QC

- Calibrate daily, pre-mobilization
- Maintain a calibration log
- Check calibration pre-mobilization, several times/sampling round
- Develop calibration acceptance criteria
- Check bias with reference solutions
- AMS: 7 successive measurements, calculate S.D.

Calibration Acceptance Criteria

- Temperature ± 1.0°C
- Specific Conductivity ± 5%
- pH ± 0.05 standard unit
- Dissolved Oxygen ± 0.2 mg/L
  or 10% saturation
- Depth 0.1m

Field Measurement QA/QC

Stabilization Criteria

- Temperature 0.2°C
- Specific Conductivity ≤100 µS/cm: <5 µS/cm
  >100 µS/cm: ± 10%
- pH ± 0.2 standard unit
- Dissolved Oxygen conc. ± 0.5 mg/L
- Depth 0.1m

QA/QC Duplicates and Blanks

- Field duplicates ≥ 10%
  - acceptance criteria 10% RPD
- Lab duplicates ~ 10%
  - acceptance criteria
    - chl-a, nutrients = 30%
    - other parameters = 15%
- Blanks
  - beginning and middle of season
  - each piece of sampling equipment

QA/QC – Checklists Multiprobe

- Resolution
- Bias
- Stabilization criteria
- AMS

QA/QC – Checklists
Contract Lab

- Lab (examples)
  - ___ Received QAPP
  - ___ MDL & ML defined
  - ___ Reporting data flags used
- Lab data validation (examples)
  - ___ Holding time limits met
  - ___ Useable MDL and ML achieved
  - ___ QC samples within expected range

QA/QC – Checklists
Field Measurements

Sampling Unit _____

Reviewed by _____ Date_____

___Multiprobe was calibrated correctly

___ Multiprobe post-calibration checks were successful

___ Field duplicates were within range

___ All field forms have been received

___ No obvious trends in data from any sensor

___ . . .

QA/QC – Checklists on Field Forms whenever possible

ACADIA NATIONAL PARK
Resource Management

Lake Survey Form

Lake: _____ Station:____
YSI/DB lake code: _____
MIDAS: _____

Date: _____
Time: _____
Surveyor: _____

SUN: ☐ Bright ☐ Cloudy ☐ Overcast
Cloud cover: _____ %

Wind Vel:_____
Wind Dir:_____
Air Temp: ___.__ °C
Surface Water Temp: ___.__°C
Measured depth where sampled: _____
☐ meters ☐ feet

Lake Level: _____ ☐ meters ☐ feet

Transparency

Secchi Depth: ___ ___.___ meters
QC Duplicate Reading: ___ ___.___ ___ meters
Did disk hit bottom? _____ ("8"= yes)
LICOR Profile completed? _____

YSI Multi-parameter Meter

DO % sat drifted high to low: ☐
Calibrate DO in field: ☐
Pressure at DO calibration: _____
DO charge before calibration (25 to 75):_____
DO % local in sat enviro (100 ± 2%):_____
DO gain local (0.7 to 1.14) after calib:_____
Calibrate depth: ☐

pH Calibration: ☐ 1-point ☐ 2-point
pH calib to: pH 7 _____ pH 4 _____
pH 7 mv: _____ pH 4 mv:_____

Water Sample Information

Sample location:
☐ Deep hole ☐ Other _____
Sample type: ☐Core ☐ Grab
Sample Depth: ____ ☐ feet ☐ meters
Sample time: _____
Sample Set:
NETN/Nutrients ☐ Acidification ☐

Notes:

Data Entry: ☐ Secchi ☐ YSI/DO/Temp ☐ Chemistry ☐ Proofed? ☐ DEP Database
Sample ID

h - [ACBUBL07.DAT]

View Comm Real-time Graph Setup Appl Window Help

DateTime	Temp	SpCond	DO%	DOsat	DO Conc	DO Cha	Depth	pH	pHmV	BP	Latitude	Longitude	Site
M/D/Y	C	uS/cm	%	%Loca	mg/L		m		mV	psi	DD.dddd	DD.dddd	
0/24/07 14:40:31	12.67	1.0	98.5	100.0	10.46	38	-0.014	6.30	30.3	14.49	0.000000	0.000000	899
0/24/07 14:43:13	13.44	34.0	96.8	98.3	10.10	38	0.000	6.83	0.6	14.49	0.000000	0.000000	0
0/24/07 14:44:57	13.46	34.0	96.6	98.1	10.08	37	0.999	6.84	-0.1	14.49	0.000000	0.000000	1
0/24/07 14:46:19	13.46	34.0	96.5	97.9	10.06	38	2.000	6.83	0.2	14.49	0.000000	0.000000	2
0/24/07 14:48:13	13.46	34.0	96.5	97.9	10.06	37	3.000	6.83	0.5	14.49	0.000000	0.000000	3
0/24/07 14:49:07	13.46	34.0	96.5	97.9	10.06	37	3.998	6.83	0.7	14.49	0.000000	0.000000	4
0/24/07 14:49:55	13.46	34.0	96.6	98.0	10.07	37	5.001	6.83	0.6	14.49	0.000000	0.000000	5
0/24/07 14:50:39	13.46	34.0	96.5	98.0	10.07	37	6.000	6.82	1.1	14.49	0.000000	0.000000	6
0/24/07 14:51:25	13.46	34.0	96.6	98.0	10.07	37	6.997	6.82	0.9	14.49	0.000000	0.000000	7
0/24/07 14:52:06	13.46	34.0	96.5	97.9	10.06	38	7.994	6.83	0.8	14.49	0.000000	0.000000	8
0/24/07 14:53:26	13.46	34.0	96.4	97.8	10.05	37	9.000	6.83	0.7	14.49	0.000000	0.000000	9
0/24/07 14:54:24	13.46	34.0	96.6	98.0	10.07	38	9.998	6.83	0.6	14.49	0.000000	0.000000	10
0/24/07 14:55:14	13.46	34.0	96.5	97.9	10.06	37	11.001	6.82	1.3	14.49	0.000000	0.000000	11
0/24/07 14:55:55	13.46	34.0	96.4	97.8	10.05	37	12.012	6.81	1.4	14.49	0.000000	0.000000	12
0/24/07 14:57:23	13.51	49.0	14.9	15.1	1.55	29	12.309	6.45	21.9	14.49	0.000000	0.000000	13
0/24/07 14:59:50	12.38	1.0	98.5	100.0	10.53	37	0.001	5.83	57.4	14.49	0.000000	0.000000	999

ress F1 NUM

Calibration checks saved with data

QA/QC – Checklists
Field Measurements

Sampling Unit _____

Reviewed by _____ Date_____

___Multiprobe was calibrated correctly

___ Multiprobe post-calibration checks were successful

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___ . . .

Minimum Detectable Difference

Trophic status parameters (TP, Chl-a, Secchi)

- Chl-a most variable
- Secchi least variable

Baseline = 10 yrs of Secchi data (1x/mo, summer)
Subsequent 20% change/yr, α=0.05, power = 80%

>10 yrs required for TP and Chl-a

(Vermont Lay Monitoring Program, Schmeltzer et al. 1989)

MDD (continued)

Baseline = 10 yrs Secchi data (1x/mo, summer)

Subsequent 20% change/yr

ά=0.10, power = 90%

(Minn. Poll. Control Agency 2005; Heiskary & Lindbloom 1993)

MDD (continued)
Past Data from GLKN Parks

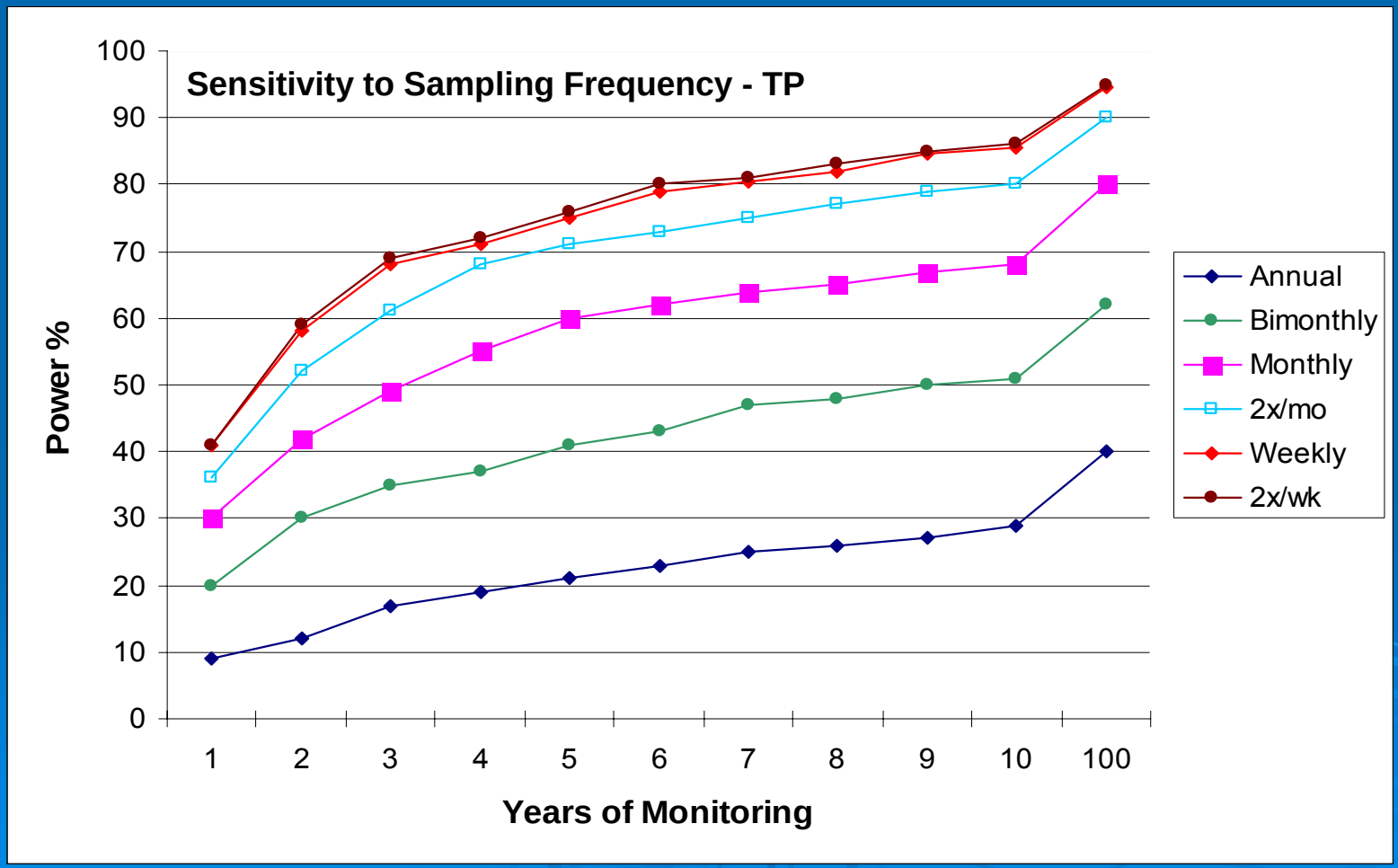
yrs to detect 20% change in DO; ά = 0.1, 1-β = .80
Sampling 3x/yr, open water season (Host, unpubl. data)

Lake (Park)	Depth Stratum	Mean (% DO)	CV	# yrs
Florence (SLBE)	1-3 m	96.8	0.051	4
Manitou (SLBE)	1-3 m	95.3	0.072	5
Chapel (PIRO)	6-7 m	7.86	0.455	19

Sampling Frequency

Monthly sampling – open water season

Biggest Bang for the Buck



Minimum Detectable Differences for Acadia lakes (as % change)

Metric	Basis	Mean	SD/Mean	MDD 8 - / +	MDD 17 - / +
Stage height	11 lakes – 2006 [1]	0.90	0.42	53% / --%	36% / 56%
Secchi depth	10 lakes – 2007 [2]	7.79	0.15	22% / 28%	15% / 17%
Specific cond	11 lakes – 2007 [3]	121	0.07	11% / 12%	7% / 8%
Min pH	11 lakes – 2006 [4]	5.73	0.24	33% / 49%	22% / 28%
Max pH	11 lakes – 2006	6.42	0.26	35% / 54%	24% / 31%
Temp – E	10 lakes – 2007 [5]	19.4	0.15	22% / 28%	15% / 17%
Temp – H	10 lakes – 2007	11.0	0.08	12% / 14%	8% / 9%
Temp – N	3 lakes – 2007	12.6	0.34	44% / 78%	30% / 43%
DO – E	10 lakes – 2007	9.01	0.06	10% / 11%	6% / 7%
DO – H	10 lakes – 2007	5.84	0.70	81% / --%	55% / --%
DO – N	3 lakes – 2007	10.1	0.13	19% / 24%	13% / 15%
Chl *a*	8 pairs – 2007 [6]	2.14	0.34	44% / 78%	30% / 43%
ANC	8 pairs – 2007	60.0	0.10	15% / 18%	10% / 11%
Apparent color	8 pairs – 2007	17.9	0.19	27% / 36%	18% / 22%
Tot P	8 pairs – 2007	4.54	0.25	34% / 51%	23% / 30%
Tot Diss P	7 pairs – 2007	2.05	0.30	40% / 66%	27% / 37%
Ortho-P	Insufficient data	--	--	--	--
Tot N	6 pairs – 2007	0.16	0.10	15% / 18%	10% / 11%
Tot Diss N	3 pairs – 2007	0.13	0.16	23% / 30%	15% / 18%
Ammonia	Insufficient data	--	--	--	--
Nitrite	Insufficient data	--	--	--	--
Nitrite + nitrate	Insufficient data	--	--	--	--

[1] Stage height was measured two to four times on 11 lakes in 2006.

[2] Secchi depth was measured two to four times on 10 lakes in 2007; an additional lake was excluded because the Secchi depth could not be measured during all attempts.

[3] Specific conductivity was measured two to five times on 11 lakes in 2007; each measurement was the average of the lake profile.

[4] pH was measured in lake profiles two or three times in 2006. SD/Mean was calculated on the hydrogen ion concentration, not the logarithmic pH scale.

[5] E refers to epilimnion measurements, and H refers to hypolimnion measurements, for 10 lakes in 2007 with two to four profiles. N refers to unlayered lake measurements, for 3 lakes in 2007 with two to three profiles (two of these lakes had layering for part of the year).

[6] For chlorophyll *a* and all water chemistry parameters, results for the core lakes were used. For several metrics, some or all measurements were below the laboratory detection limit, so these samples were excluded.

GLKN Acknowledgements

- Field Sampling Crews

  >20 people 2006-2007

- Park Staff

  Full support of natural resources, maintenance, law, interpretation.

  Boat logistical support – crucial

- GLKN Staff

NETN Acknowledgements

- Field Sampling Crews
  - > Park staff & volunteers, NETN staff, UVM contractors 2006-2007
- USGS
  - > Protocol development, training, tech support
  - > Analysis at National Water Quality Laboratory (Denver, CO)
- University of Vermont
  - > Monitoring NETN parks excepting Acadia
- University of Maine
  - > Analysis at Sawyer Environmental Chemistry Research Laboratory
- NETN Staff
- NPS-WRD